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DIFFERENCES IN THE PERCEPTION OF SOUND/RHYTHM AND THE EFFECT ON GYMNASTICS PERFORMANCE IN MICROGRAVITY (The ZER0gMN Project)

Amalia Tinto
Centro Studi Attivitá Motorie- Istituto Superiore di Educazione Fisica di Torino CSAM-ISEF, Turin, Italy
tintoamalia@libero.it

Maria Rosa Rosato
Centro Studi Attivitá Motorie- Istituto Superiore di Educazione Fisica di Torino CSAM-ISEF, Turin, Italy
rosatomr@libero.it,
Irene Lia Schlacht
Technische Universität Berlin, Berlin, Germany, irene.lia.schlacht@gmail.com
Melchiorre Masali
Università degli Studi di Torino, Turin, Italy, (retired professor) melchiorre.masali@gmail.com
Margherita Micheletti Cremasco
Università degli Studi di Torino,Turin, Italy, margherita.micheletti@unito.it

ABSTRACT

Rhythmic Gymnastics in Microgravity to Improve the Human Movement Space is the theme of a project (ZER0gYMN) we have attempted to develop with rhythmic athletes using either the facilities offered by the space industry in Turin or 0g situations like parabolic flights. The immediate aim of the proposal is to evaluate the differences in the perception of sound/rhythm and the effect on performance in gymnastics engagement on Earth and in microgravity, taking advantage of the opportunity to study this particular aspect of human movement and the feeling expressed by this Olympic sport. Gymnastics is an activity that is essentially "gravitation based". We present some physical training exercises aimed at orientation education in space as a function of microgravity. Three areas/sectors have been identified: on the ground, with tools, and in the water. Exercises under earthly conditions were presented in ten gym work session.

Keywords: Microgravity, Human Movement, Rhythmic Gymnastics, 0g/µg Exercises

1.1 Foreword

In-flight student experiments, whether proposed or personally exploited in microgravity, may represent a valid opportunity to solve somewhat insightful questions notwithstanding their great educational significance in the field of human performance in microgravity. We may occasionally remember the Skylab, Motor Sensory Performance, Student Experiment, ED-41 proposed by Kathy L. Jackson of Houston (1973), or our CROMOS experiment on color and brightness perception performed in 2006 during an ESA student parabolic flight.

Gymnastics may have high potential for astronauts. In particular, we want to investigate rhythmic gymnastics, not to teach astronauts but to seek new methods and potentials in the field.

According to Smith *et al.* (2012), exercise has shown little success in mitigating bone loss from long-duration spaceflight. Nevertheless, their data document that resistance exercises, coupled with adequate energy intake and vitamin D, can maintain bone mass in most regions during 4- to 6-month missions in microgravity. This is the first evidence that improving nutrition and resistance exercise during spaceflight can attenuate the expected bone mineral density deficits previously observed after prolonged missions.

Much research has focused on the relationship between exercise and the maintenance of bone structures, but bone metabolism is not the only motivation for the study of movement in Space; there is also the habit of body orientation and the maintaining of movement rhythms control in the interaction with environment and people. These topics are of interest in the studies of human adaptation to extreme environment dynamics considering its physical, physiological, biomechanical and perceptual features. Moreover, we emphasize from the specific standpoint of this study on the capacity to express motion and motion control in sports techniques.

Accordingly, the aim of this first experiment is to evaluate plausible differences regarding the perception of sound/rhythm in microgravity (0g/µg) conditions, in gymnastic actions, studying the particular aspects of human movement and the sensitivity expressed by Rhythmic Gymnastics (RG), as well as promoting the physical activity themes and education to movement in Space. Notwithstanding the classic Skylab athletic experiments (NASA, 2008), as demonstrated by the Kitsou Dubois (Dubois, 2001) experimentation, gymnastics and choreography can be performed in 0g/µg, which offers a new opportunity for further studying human movement. The compensation of gravity in parabolic flights can allow studying the

perception of rhythm in 0g / µg and the actions that can be performed by the gymnast. Also the compensation of underwater gravity could be used to develop the technique (according to K. Dubois). A first evaluation of the feasibility of testing specific motor activities in microgravity has already been implemented during a parabolic flight experiment at ESA (European Space Agency) with performers of very different body build: Irene L. Schlacht (5th percentile ♀) and Henrik Birke (95th percentile ♂) mention that through the state of weightlessness, the dynamic conditions of certain movements are modified. Everything loses its weight and retains its mass. Sources of information provided by the gravitational force disappear, but the visual structures of the environment are maintained. The body schema is certainly changed. Its sensory-motor and perceptual system are different from its usual environment of life. Through their reciprocal relations, the individual will have to adapt to this new condition. Through the process of adaptation, the astronaut must redefine its own world and build a body of knowledge on the environment and experimental procedures designed to exploit it. It will therefore be faced with the need to perform an adequate behavioral strategy appropriate for the circumstances of the moment (Tafforin, 1993).

The absence of gravity is also seen as sensory assault: an astronaut faces unusual conflicts in the reception of sensory messages. Thus, there appears an "evil space" kind of disease of adaptation. A manifestation of this disease is a feeling of anxiety with decreased alertness, fatigue, and apathy encountered during kinetosis. The sensory conflict is intra-vestibular and visual-vestibular, remodeling the body schema and changing the fluid distribution; modifying digestion, due to the non-stimulation of the mechanoreceptors of the gastric wall; ultimately, fatigue and psychological stress can play a supporting role.

Being an experienced parabolic flyer, the performance of the choreographer and dancer Kitsou Dubois in microgravity shows the extraordinary work of adaptation that is possible through the job of a dancer (Dubois, 1994, Bureaud, 2009).

1.2. The Project

Our ZER0gYMN project (Rosato *et al.,* 2012) was devised in view of an ESA Student Parabolic Flight Project that was planned to investigate the relationship between Gymnastics (the Rhythmic specialty in particular) movement and visual orientation in 0g from a neutral posture. In recent years, this orientation of the study has involved rhythmic gymnastics experts leading to motivating contributions to theoretical research but increasing the possibilities of simulation and experimentation (Masali *et al*., 2010). The chance and the challenge were to find out whether Rhythmic Gymnastics exercises specifically structured to express the complexity of this type of extreme physical activity could make an important contribution to studies on human movement when deprived of their most important parameter: *weight*. A further aim of the proposal was to contribute to increasing the component of well-being in studies of habitability during long-duration space missions, where physical activity becomes an important factor for the success and efficiency of the astronauts. The project is at present only a preparation study as the kind of experiment (not technological, involving humans in the experimentation and the requirements of room and safety devices on the aircraft) precluded these tests from actually being carried out.

3. Issues and Problem

We devised various exercises intended for physical training and orientation education intended to make the living conditions in a microgravity environment more suitable and to exploit their actual feasibility. The choice of the exercises and the definition of the protocol under earthly conditions were determined by preliminary investigations on focused Gymnastics techniques carried out during a parabolic flight (Schlacht *et al.* 2007).

We identified three areas / sectors: on the ground, with the use of specific tools (rings, elastic supports, and bar), and underwater. We present below some of the 10 exercises prepared under earthly conditions in ten gym sessions (Tinto *et al.*, 2011).

4. The Exercises

The series of ground exercises were designed to gradually educate the body to be consciously aware of positions and movements characterized by a continuous form and with the use of planes and axes combined in different ways. The player should be required to perform the exercises at different paces to obtain different degrees of muscle exploitation. We present some examples of those who best represent types of rhythmic movements that we feel are particularly useful in the µg/0g context.

In particular, exercise 3 (of Figure 1) is carried out in the frontal plane and is characterized by an imbalance of the body obtained with the support of the hands to the ground and behind a limb back-high unbalance, inverted forward and back upright.

Exercise 7 (of Figure 2) consists of rotations of the body on the longitudinal axis of 360 ° and over, carried out in different positions: the first from a position on the floor with divaricated sagittal of the lower limbs, the other with departure from assuming the upright position, the bust flipped forward and elevation of a limb back-up. Basically this is the flipping of the body on a limb only with rotation of the longitudinal axis.

Finally, exercises 9 and 10 (of Figures 3 and 4) may be regarded as an approach to the next step, which should provide for exercises in the air phase with the help of different tools (rings, elastic supports, and bar). Exercise 9, in pairs, consists of performing a position in support of a companion, while exercise 10 carries out a tilting guided by two companions that support and help the tipping, starting by lifting the body

upwards. It is therefore supported toward the air microgravity phase, because the companion-companions are anchored to the floor.

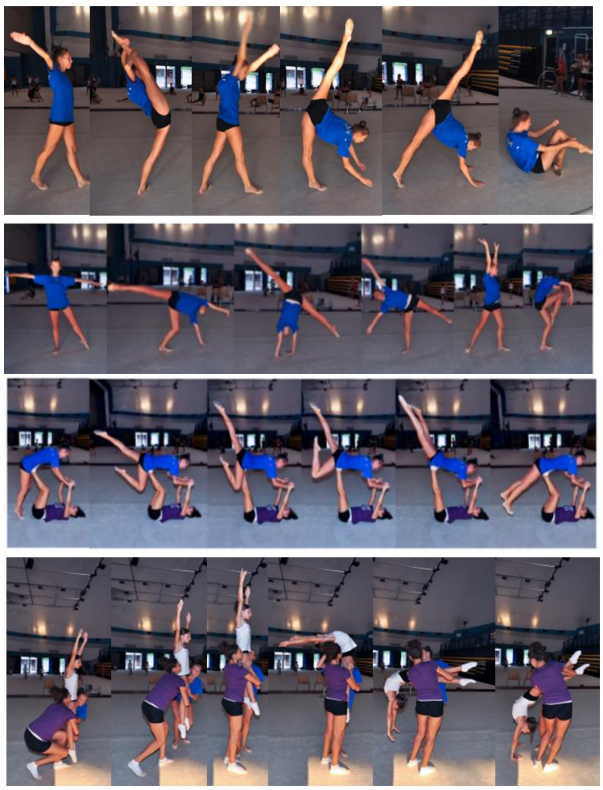

Image: Fig. 1, 2, 3, 4 from top to bottom show the protocolled exercises n°#3;#7;#9;#10, respectively.

1.5. Future Research Directions

Our experience in microgravity shows that in order to move in a very determined way following exactly the prescribed exercises, there are two possibilities:

1. Having a connection point to use as a pivot to move the body: e.g., Kitsou Dubois coordinates her movements with hands clinging to a chair anchored to the floor.
2. Having a helper anchored to the floor: e.g., Irene Schlacht and Henrik Birke were moved by the person secured to the ground with straps on the feet.

Considering the application of these exercises in the µg/0g context, it is clear that for exercises #9 and #10, the anchorage quandary, which is essential to solve in the absence of gravity, is easily solved by stabilizing the supporting companion/s (as it was in the Schlacht/Birke preliminary trial during the above-mentioned ESA parabolic flight), while for the individual free body exercises devised in the gravitational field, weak-tight Velcro® strips only at the support end points of the limbs may allow switching between the anchor points. We alternatively foresee that the gymnast may use fixed media such as bar, parallel bars, rings and suspended sheets which are the common media of Artistic Gymnastics. An exercise protocol is at present being devised to integrate Rhythmic Gymnastics with Artistic Gymnastics to solve the anchoring difficulties in order to better define the proposed study of movement and rhythm in different levels of gravity and experimental conditions (underwater, parabolic flights and 0g Space).

Technical difficulties and environmental changes in the regulations have been delaying the possibility of continuing the experiment in microgravity. The preparation of specific exercises developed in an environment of neutral buoyancy increasingly using collaborative structures, aerospace industrial environment existing in Turin, the exchange of actual experiences with the Technical University of Berlin and ESA-ESTEC, has allowed developing this new field of investigation.

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Presenters at the IAC Conference

- Irene Lia Schlacht: irene.lia.schlacht@gmail.com
Milan: +39 320 3168 723 Berlin: +49 0176 3588 2695

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DIFFERENCES IN THE PERCEPTION OF SOUND/RHYTHM AND THE EFFECT ON GYMNASTICS PERFORMANCE IN MICROGRAVITY

Tinto A.[1*], Rosato M.R.[1], Masali M.[2], I.L. Schlacht[3], M. Micheletti Cremasco[2]

[1] Centro Studi Attività Motorie- Istituto Superiore di Educazione Fisica di Torino CSAM-ISEF- *Università di Torino
[2] Università di Torino Dipartimento di Scienze della Vita e Biologia dei Sistemi
[3] Technische Universität Berlin - Politecnico di Milano, Extreme-Design research group
(Contact of the presenter: Irene Lia Schlacht irene.lia.schlacht@gmail.com +39.320.3168.723)

image left: Gymnastic as µg Countermeasure
(*Phobos Project*, Schlacht *et al*., 2005 ESA Student Workshop)

ABSTRACT

Rhythmic Gymnastics in Microgravity to Improve the Human Movement Space is the theme of a project (ZER0gYMN) we have attempted to develop with rhythmic athletes using either the facilities offered by the space industry in Turin or 0g situations like parabolic flights. The immediate aim of the proposal is to evaluate the differences in the perception of sound/rhythm and the effect on performance in gymnastics engagement on Earth and in microgravity, taking advantage of the opportunity to study this particular aspect of human movement and the feeling expressed by this Olympic sport. Gymnastics is an activity that is essentially "gravitation based". We present some physical training exercises aimed at orientation education in space as a function of microgravity. Three areas/sectors have been identified: on the ground, with tools, and in the water. Exercises under earthly conditions were presented in ten gym work sessions.

INTRODUCTION - ZER0gYMN Parabolic Flight Project HUMAN MOTION IN MICROGRAVITY

In-flight student experiments, whether proposed or personally exploited in microgravity, may represent a valid opportunity to solve somewhat insightful questions notwithstanding their great educational significance in the field of human performance in microgravity (e.g. our CROMOS experiment during a 2006 ESA student parabolic flight). Gymnastics may have high potential for astronauts. Much research has focused on the relationship between exercise and the maintenance of bone structures (Smith *et al.*, 2012), but bone metabolism is not the only motivation for the study of movement in Space; there is also the habit of body orientation and the maintaining of movement rhythms control in the interaction with environment and people. These topics are of interest in the studies of human adaptation to extreme environment dynamics considering its physical, physiological, biomechanical and perceptual features.

The aim of this first experiment proposal is to evaluate plausible differences regarding the perception of sound/rhythm in microgravity (0g/µg) conditions in gymnastic actions expressed by Rhythmic Gymnastics (RG), as well as to promote the issues of physical activity and movement education in Space. As demonstrated by the Kitsou Dubois (Dubois, 2001) experiment, gymnastics and choreography can be performed in 0g/µg, which offers a new opportunity for further studying human movement. A first evaluation of the feasibility of testing specific motor activities in microgravity was already implemented during a parabolic flight experiment at ESA (European Space Agency) with performers of very different body build: Irene L. Schlacht (5th percentile ♀) and Henrik Birke (95th percentile ♂). Through the process of adaptation, an astronaut must redefine his or her own world and build a body of knowledge regarding the environment and experimental procedures designed to exploit it. He or she will therefore be faced with the need to execute an adequate behavioural strategy appropriate for the circumstances of the moment (Tafforin, 1993).

The absence of gravity is also seen as sensory assault. An astronaut faces unusual conflicts in the reception of sensory messages. Thus, there appears an "evil space" kind of disease of adaptation. One manifestation of this disease is a feeling of anxiety with decreased alertness, fatigue, and apathy encountered during kinetosis (Dubois, 1994, Bureaud, 2009). Just like the experience of flying, Kitsou Dubois says that, paradoxically, these difficulties show the extraordinary work of adaptation that is the job of a dancer.

Our ZER0gYMN project (Rosato *et al.*, 2012) was devised in view of an ESA Student Parabolic Flight Project that was planned to investigate the relationship between Gymnastics (the Rhythmic specialty in particular) movement and visual orientation in 0g from a neutral posture. The project is at present only a preparation study as the kind of experiment (not technological, involving humans in the experimentation, plus the requirements of room and safety devices on the aircraft) precluded these tests from actually being carried out.

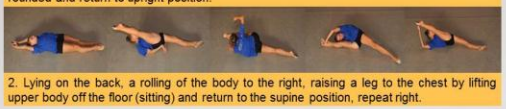
0g Experiment CROMOS- ESA Student Parabolic Flight, Bordeaux, 2006

GRAVITY ZERO: KITSOU DUBOIS the Control and Movement of the Body in Microgravity: Insights from a Dancer's Research in Parabolic Flight

EXERCISES FOR PHYSICAL PREPARATION AND EDUCATION TO SPACE ORIENTATION

We devised various exercises intended for physical training and orientation education intended to make the living conditions in a microgravity environment more suitable and to exploit their actual feasibility. The choice of the exercises and the definition of the protocol under earthly conditions were determined by preliminary investigations on focused Gymnastics techniques carried out during a parabolic flight (Schlacht *et al.* 2007). We identified three areas / sectors: on the ground, with the use of specific tools (rings, elastic supports, and bar), and underwater. We present below some of the 10 exercises prepared under earthly conditions in ten gym sessions (Tinto *et al.*, 2011). The series of ground exercises were designed to gradually educate the body to be consciously aware of positions and movements characterized by a continuous form and with the use of planes and axes combined in different ways. The person should be required to perform the exercises at different paces to obtain different degrees of muscle exploitation. We present some examples of those who best represent types of rhythmic movements that we feel are particularly useful in the µg/0g context.

1. Upright, legs slightly apart with pelvis retroversion and lower limbs half bent, spine rounded and return to upright position.



2. Lying on the back, a rolling of the body to the right, raising a leg to the chest by lifting upper body off the floor (sitting) and return to the supine position, repeat right.

3. Standing, step left forward momentum of the right leg forward, resting on the ground of the right leg and the left leg immediate impetus behind high with trunk bent forward, upside down forward and return to the upright position.

4. Upright, forward inverted and finish on the feet, legs bent sideways overturning below with rolling on back and arrival in the upright position.

5. In pairs, one performs the vertical and the partner tries to destabilize the position of the legs pushing in different directions.

6. Body posture in *shoulderstand*, small alternating outbursts in the sagittal plane and a bigger push of a limb (forward or reverse) hit the ground on back or flipping body back.

7. Tilting of the body around the anterior-posterior axis (wheel), arrival and trunk half-bent forward (free limb flexed).

8. Tours of the body resting on a forefoot (free limb in different positions, arabesque, attitude, passé)

9. In pairs, one on his back with legs bent and arms stretched forward as a support for the partner who assumes different positions (upright with shoulders in support on the hands of the companion, tense body with support of the hips on the hands of the mate), depending on the preparation of the gymnasts the exercise can be made on different technical level positions.

10. With the help of several companions raise up a gymnast from the ground with power on the lower limbs (arms and body straight up), the gymnast performs a back bend and, aided by his companions, puts his/her hands on the ground and flips.

DISCUSSION AND PERSPECTIVES

Considering the application of these exercises in the µg/0g context, it is clear that for exercises 9 and 10, the anchorage quandary, which is essential to solve in the absence of gravity, is easily solved by stabilizing the supporting companion/s (as it was in the Schlacht/Birke preliminary trial during the above-mentioned ESA parabolic flight), while for the individual free body exercises devised in the gravitational field, weak-tight Velcro® strips only at the support end points of the limbs (and/or the back for exercises 2, 4 and 5) allow switching between the anchor points. We alternatively, foresee that the gymnast may use fixed media such as bar, parallel bars, rings and suspended sheets, which are the common media of Artistic Gymnastics. An exercise protocol is at present being devised to integrate Rhythmic Gymnastics with Artistic Gymnastics to solve the anchoring difficulties in order to better define the proposed study of movement and rhythm in different levels of gravity and experimental conditions (underwater, parabolic flights and 0g Space). Technical difficulties and environmental changes in the regulations have been delaying the possibility of continuing the experiment in microgravity. The preparation of specific exercises developed in an environment of neutral buoyancy increasingly using collaborative structures, aerospace industrial environment existing in Turin, and the exchange of actual experiences with the Technical University of Berlin and ESA-ESTEC has allowed developing this new field of investigation.